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Tolerance for distorted faces: challenges to a configural processing account of familiar face recognition

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Abstract

Face recognition is widely held to rely on ‘configural processing’, an analysis of spatial relations between facial features. We present three experiments in which viewers were shown distorted faces, and asked to resize these to their correct shape. Based on configural theories appealing to metric distances between features, we reason that this should be an easier task for familiar than unfamiliar faces (whose subtle arrangements of features are unknown). In fact, participants were inaccurate at this task, making between 8% and 13% errors across experiments. Importantly, we observed no advantage for familiar faces: in one experiment participants were more accurate with unfamiliar faces, and in two experiments there was no difference. These findings were not due to general task difficulty – participants were able to resize blocks of colour to target shapes (squares) more accurately. We also found an advantage of familiarity for resizing other stimuli (brand logos). If configural processing does underlie face recognition, these results place constraints on the definition of ‘configural’. Alternatively, familiar face recognition might rely on more complex criteria – based on tolerance to within-person variation rather than highly specific measurement.

The concept of ‘configural processing’ is central to the study of face perception. It is widely held that viewers are sensitive to the relationship between facial components, and that they recruit this sensitivity to make perceptual judgements. This concept lies at the heart of many proposals concerning face identification (e.g. Diamond & Carey, 1986; Maurer Le Grand & Mondloch, 2002; Richler, Mack, Gauthier, & Palmeri, 2009). It is also a key component of explanations for many other aspects of face perception, for example the inversion effect (Searcy & Bartlett, 1996; Leder & Bruce, 2000; McKone & Yovel, 2009), similarity effects (e.g. Rhodes, 1988) and certain aspects of emotional processing (Calder, Young, Keane & Deane, 2000; McKelvie, 1995). In fact, the term ‘configural processing’ includes a wide range of theoretical positions (see below). In this paper, we address one of these: an interpretation of configuration in terms of the metric distances between facial features. We are specifically concerned here with familiar faces, and we ask how well this view of configural processing is able to account for their recognition.

Maurer et al (2002) provide an influential analysis, which distinguishes between three types of configural processing: (i) detection of ‘first-order’ relations, which define the basic arrangement of a face (eyes above nose, above mouth); (ii) holistic processing, which coheres the features into a perceptual gestalt; and (iii) sensitivity to second order relations, or “perceiving the distances among features”. Maurer et al demonstrate that these three types of processing are behaviourally dissociable, with each being involved in different perceptual tasks. However, despite this analysis, there is still some ambiguity in the literature, with some authors using ‘holistic’ and ‘configural’ interchangeably, and some being unclear about which form of configural processing is being recruited to explain a particular effect.

To be as clear as possible, we are here concerned only with second-order configural processing, and the ways it has been used to explain familiar face recognition. This is posed directly by Richler et al (2009): “Because faces are made from common features (eyes, nose, mouth, etc.) arranged in the same general configuration, subtle differences in spatial relations between face features being encoded [are] particularly useful for successful recognition of a given face.” (p. 2856). This version of configural processing is sometimes made even more explicit, for example by Tanaka & Gordon (2011) who write “We use the term ‘configural processing’ ... to refer to

encoding of metric distances between features (i.e. second-order relational properties)” (p.178).

This paper presents three experiments that challenge the use of metric distances in identification. In fact, some constraints already exist in the literature, though these are often passed over. In one important demonstration, Hole, George, Eaves, & Rasek, (2002) showed that stretching photos by up to 200% vertically, and hence destroying their original aspect ratio, had no effect at all on recognition of faces. This is a very striking result. All relationships between metric distances which cross more than one dimension are destroyed by this transformation (i.e. all angles, all ratios of distances except in a single dimension). If we really recognise one another by the ‘subtle differences in the spatial relations between face features’ then it is perhaps surprising that these subtle differences survive such a radical assault. Using very different techniques, Taschereau-Dumouchel, Rossion, Schyns & Gosselin (2010) showed that the information available from interattribute distances within a face is small, by comparison to information available from other sources (e.g. skin properties). Using *unfamiliar* faces, they demonstrated poor performance in a match-to-sample test when faces differed on interattribute distances only.

Schwaninger, Ryf, & Hofer, (2003) studied people’s abilities explicitly to gauge configural information, and found them poor. Observers were asked to judge the distance between the eyes or between the eyes and mouth of 10 unfamiliar faces. A comparison stimulus (a horizontal or vertical line) was adjusted to match these distances within a face. Observers made very large errors (39% for eye-mouth distance and 11% for inter-ocular distance). The authors conclude that processing information is different in perceptual as opposed to recognition tasks - interestingly taking it as read that configural processing is used in recognition tasks.

There have also been challenges in the ERP literature. For example, Bindemann, Burton, Leuthold, and Schweinberger, (2008), showed a lack of sensitivity to linear distortion in the face-identity-sensitive ERP component, N250r. Furthermore, Caharel, Fiori, Bernard, Lalonde, and Rebaï (2006) demonstrated that altering distances between features in famous faces did have a significant effect on the N170 component, but did not affect recognition. These results seem to support the idea that,

while metric distance change does affect the appearance of a face, and can have an affect on early face processing (Caharel et al, 2006), they may not be critical in face *identification*.

In recent work, we have begun to focus on the issue of within person variability (Jenkins, White, van Montfort, & Burton, 2011; Burton, 2013). The central observation is that different pictures of the same face are highly variable. Indeed, for many measures, within-person variability exceeds between-person variability (Jenkins et al, 2011). This raises an interesting problem: if we recognise people by their characteristic ‘metric distances between features’, then how are we to find such distances in highly variable images of the same person? Alternatively, we might expect that as we become familiar with a face, we actually become *more tolerant* of differences between images – it is well-established that unfamiliar face-matching is more closely tied to superficial image characteristics than familiar face matching. For example, Clutterbuck and Johnston (2004) demonstrate that viewers’ ability to match two different photos of a face is a good index of their level of familiarity with that person. This suggests that learning a face actually involves learning the range of variability that it can adopt – rather than learning highly specific representations of distances between features.

In the experiments below, we test a hypothesis derived from a configural processing view of familiar face recognition (in the sense of metric distances, described above). We employ a task which is intended to access people’s representations of familiar faces: Viewers are shown faces in the wrong aspect ratio, and simply asked to adjust these images to eliminate the distortion. Our prediction, derived from configural processing, is that viewers will be good at this task for familiar faces. The core premise of face recognition is the acquisition of a cognitive representation of a person’s unique identity which can be used in subsequent encounters for recognition purposes. Therefore, if face recognition relies on ‘subtle differences of spatial relations between face features’ then recognizers must have a good representation of these subtle differences, on which to base their judgments, leading to accurate performance with familiar faces. On the other hand, there seems no reason to predict that people will be very good at this task for unfamiliar faces. It should be relatively easy to adjust images to roughly face-shape (perhaps relying on knowledge of first-

order configuration), but detailed spatial differences should be unknown – for example a viewer would not know whether a distorted unfamiliar face depicted someone with a relatively long face or a relatively fat face. We therefore predict that there will be a clear advantage for familiar over unfamiliar faces in this task.

Experiment 1

Methods

Participants

Thirty undergraduate students (19 female; average age 22.3 years) participated in exchange for course credit. All participants were native to the UK and had normal or corrected-to-normal vision.

Stimuli

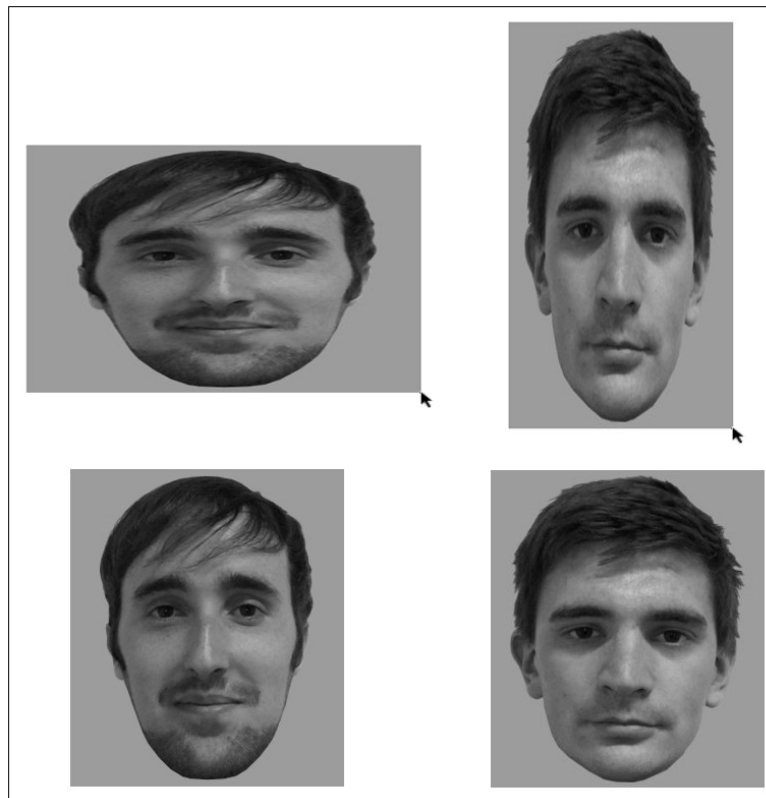


Figure 1: Examples of stimuli to resize (top), and correct aspect ratio (bottom)

Images of 15 familiar (British) and 15 unfamiliar (Australian) celebrities were taken from a UK/Australian database, developed for cooperative research. Pre-checks with UK participants from the same population (but not used in the main experiments) confirmed that they were familiar with the British, but not the Australian faces. Images were front-view or near front-view, under various luminance conditions and with no constraint on expressions. External features were kept intact, and other extraneous details (i.e. clothing and background) were cropped. Images were presented in grayscale against a light gray background and the originals measured 269px x 312px (9.49cm x 10.97cm), subtending approximately $7.76^\circ \times 8.96^\circ$ of visual angle at a viewing distance of 70cm. Copyright restrictions prevent us from reproducing the images of these celebrities. A list is given in the Appendix, and Figure 1 shows examples of faces presented in the same way.

Procedure

Images were presented individually in an arbitrary aspect ratio. For each trial, x and y dimensions were scaled to random values between 50% and 200% of their original (generated and presented by an underlying Matlab program). Participants were asked to re-size the window in the normal manner, using a mouse controlling a cursor. They were instructed: “Please adjust the window until the image looks right”. Participants completed 4 practice trials that presented front-view images of cars followed by 30 trials of faces (15 familiar), in random order. The experiment was self-paced, and participants were asked to be as accurate as possible.

Results & Discussion

Aspect ratio accuracy was measured by $(Y_{\text{final}}/X_{\text{final}})/(Y_{\text{original}}/X_{\text{original}})$. Under this definition, absolute size of the adjusted image is irrelevant to accuracy – which depends on aspect ratio alone. Perfect accuracy gives a value of 1, with larger values represent images ‘too tall’, and values less than one being ‘too wide’.

Mean absolute errors ($\text{abs}(\text{aspect ratio accuracy} - 1)$), are shown in table 1. A paired samples t-test showed that errors were significantly greater in the familiar than the unfamiliar condition, $t(29) = 3.20, p < .01, \eta_p^2 = .26$.

Table 1. Experiment 1: Mean absolute error by condition (SDs in parentheses)

	Mean Absolute Error
Familiar	0.134 (0.037)
Unfamiliar	0.119 (0.024)

This is rather a surprising result. First, participants made *greater* errors for familiar than unfamiliar faces, directly counter to our prediction derived from a configural processing account of familiar face recognition. Second, the size of the errors (13.4% and 11.9%) each differed significantly from zero (one-sample t-tests for familiar faces, $t(29) = 19.99$, $p < .001$, $\eta_p^2 = .93$, and unfamiliar faces, $t(29) = 27.37$, $p < .001$, $\eta_p^2 = .96$ respectively).

Absolute error rates do not give an indication about whether participants showed consistent bias, generally scaling images ‘too tall’ or ‘too wide’, and so the following analysis examines this. We were also interested to know whether the aspect ratio of the initial presentation had an effect on participants’ behaviour. For example, in trials where the initial presentation was ‘too tall’, might participants tend to rescale the image ‘too wide’, in a way analogous to facial adaptation? To examine this, we compared mean aspect ratio (preserving sign) as rescaled by participants. Trials were broken down into those for which images had originally been presented ‘too tall’ and those which had originally been presented ‘too wide’. Table 2 gives mean rescaled aspect ratios.

Table 2. Experiment 1: Mean scaled aspect ratios by condition (SDs in parentheses).

	Initially too tall	Initially too wide
Familiar faces	1.122 (0.067)	1.015 (0.084)
Unfamiliar faces	1.090 (0.072)	0.992 (0.182)

A 2 (familiarity) x 2 (initial aspect ratio) ANOVA showed a main effect of initial aspect ratio, $F(1, 29) = 31.0$, $p < .001$, $\eta_p^2 = .517$, but no main effect of familiarity, $F(1, 29) = 2.8$, $p = .106$, $\eta_p^2 = .088$, and no interaction, $F(1, 29) < 1$. So, images

originally seen ‘too tall’ tended to be rescaled taller than those seen too wide. However, there was no evidence of an adaptation effect. (We repeated this analysis for experiments 2 and 3 below, but as there was no suggestion of adaptation, we do not report this data further.)

In sum, participants were worse at performing the aspect ratio task for familiar than for unfamiliar faces (table 1). Explanations of face recognition based on metric distances between features seem to imply that observers should be very accurate in representing the aspect ratio of familiar faces, making fewer – or, indeed, no – errors. Because this is a rather counter-intuitive result, we replicated it in Experiment 2, using a slightly different presentation mode. In Experiment 1, all source photos had the same overall size and aspect ratio, because each face had been dropped into the same size grey background. It is therefore possible that participants could learn the ‘correct’ aspect ratio over the course of the whole experiment, and aim to readjust all images to this. Although such a strategy would not seem to affect the prediction derived from configural processing (an advantage for familiar faces), in the second experiment we eliminated this feature of the stimuli, using source photos with a wide variety of sizes and aspect ratios. We also examined whether the task could be insufficiently sensitive to reveal *any* systematic differences. Perhaps participants are simply inaccurate when resizing windows in general, and the noise this produces means that it is impossible to detect any underlying differences between familiar and unfamiliar faces. In Experiment 2 we test this possibility by comparing participants’ ability to resize faces with their performance on a non-face pattern, specifically a simple geometric color patch.

Experiment 2

Methods

Participants

Thirty undergraduate students (20 female; average age 21.1 years) participated

in exchange for course credit. All were native to the UK and had normal or corrected-to-normal vision.

Stimuli

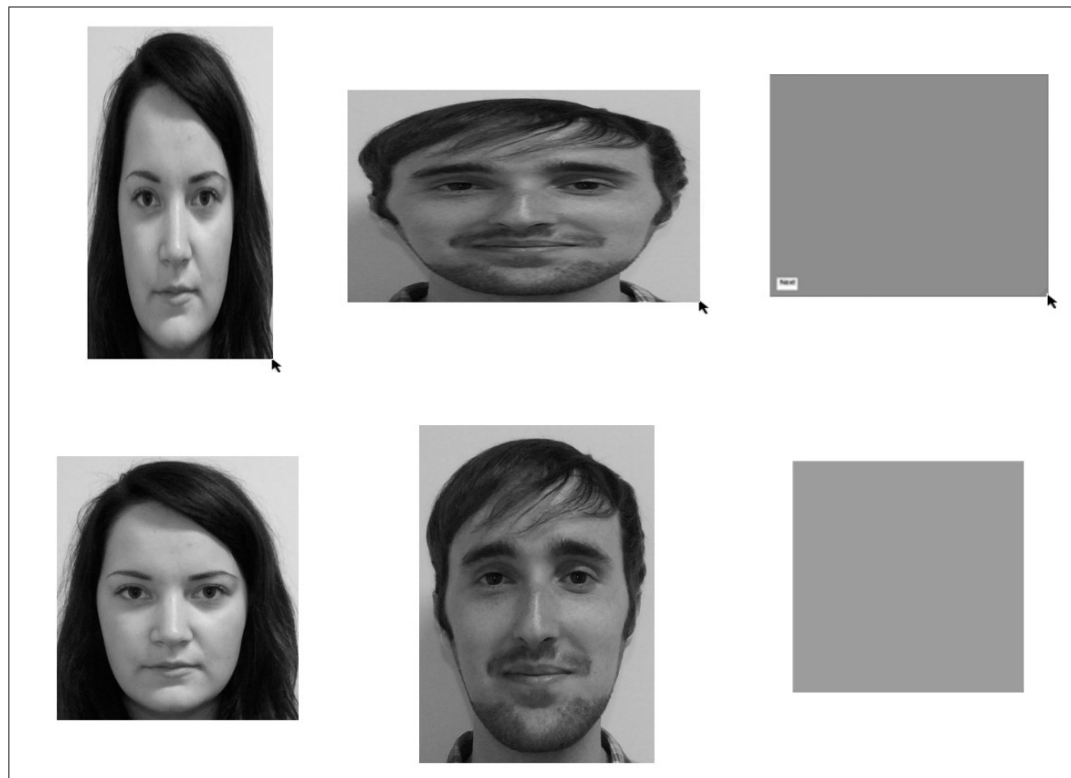


Figure 2: Examples of stimuli to resize (top), and correct aspect ratio (bottom)

Stimuli were taken from the same database of faces as Experiment 1. However, whereas stimuli for Experiment 1 had been dropped into a standard sized rectangle, the stimuli used here were cropped from the original images (sourced from the internet) and had a range of sizes and aspect ratios (smallest 195x281 to largest 1059x1188). Once again, copyright restrictions prevent us from reproducing the images of these celebrities, but figure 2 shows examples of faces presented in the same way. In this experiment we also used square color blocks. Fifteen squares were created and filled with different gray levels. The square dimensions measured a range from 225x225px to 754x754 pixels (see figure 2).

Procedure

The experimental procedure was the same as in Experiment 1. For each trial, x and y dimensions were scaled to random values between 50% and 200% of their original. If

this led to an image exceeding the screen display size, the whole image was rescaled to fit the display (maintaining the aspect ratio determined by the trial-by-trial randomization procedure). Each participant completed 8 practice trials. There followed 45 experimental trials of faces and squares (15 familiar and 15 unfamiliar faces, 15 squares) intermixed and presented in separate random order for each participant. Participants were instructed: “For faces, please adjust the window until the image looks right. For color blocks, please adjust the window until the block shows a square”.

Results and Discussion

Mean absolute errors are shown in Table 3. Repeated measures ANOVA revealed a significant effect of stimulus type, $F(2,58) = 15.0, p < .001, \eta_p^2 = .34$. Planned comparisons (Bonferroni corrected) showed no difference between familiar and unfamiliar faces ($t(58) < 1$). However, adjustment of squares was significantly more accurate than adjustment of either of the face conditions (familiar faces v. squares: $t(58) = 4.64, p < .001, \eta_p^2 = .27$; unfamiliar faces v. squares ($t(58) = 4.49, p < .001, \eta_p^2 = .26$).

Table 3. Experiment 2: Mean absolute errors by condition (SDs in parentheses)

	Observer Absolute Errors
Familiar Faces	0.083 (0.029)
Unfamiliar Faces	0.082 (0.026)
Squares	0.057 (0.019)

This is a different task to Experiment 1, in that participants were not trying to rescale all images to the same size – instead every image had its own unique aspect ratio. However, we have once again failed to find any evidence for an advantage of familiar over unfamiliar faces in this task. Both were significantly worse than a condition in which participants were asked to re-scale a geometric patch of colour – suggesting that the task is sensitive enough to reveal real differences where they exist.

Having established that this image-rescaling task is sensitive to gross stimulus differences (faces v. squares), we now ask whether it is sensitive to familiarity in stimuli other than faces. Perhaps the reason we have found no advantage for familiar over unfamiliar faces is that viewers are simply insensitive to the aspect ratio in stimuli encountered day to day. In the next experiment, we showed participants brand logos that would be familiar or unfamiliar to them, and once again asked them to correct aspect ratio-distorted images. The presentation of such logos (for example, the ‘tick’ of a famous sports brand) is tightly controlled by companies using them, and we can assume wide exposure to the correct versions. Using familiar and unfamiliar logos therefore allows us to test for the effects of familiarity in a non-face stimulus set.

Experiment 3

Methods

Participants

Sixty undergraduate students (28 female; average age 21.6 years) participated in exchange for course credit. Participants who saw the face stimuli were native to the UK. All participants had normal or corrected-to-normal vision.

Stimuli and Procedure

In Experiment 3, we used the same face images as in Experiment 2 plus thirty company logos, half familiar and half unfamiliar (see figure 3). The familiar logos were chosen to be well-known in the UK, and therefore by our UK participants. The unfamiliar logos were chosen to be of similar complexity, but for companies not well known in the UK (these were mostly large Canadian organisations). A list is given in the appendix. A post-experiment check showed that participants could, on average, correctly name 14.0 of the familiar logos, and 0.23 of the unfamiliar logos.

Half the subjects completed trials using faces, and half completed logo trials. Other than that, the experimental procedure was the same as in Experiment 2. For each trial,

x and y dimensions were scaled to random values between 50% and 200% of their original value. If this led to an image exceeding the screen display size, the image was rescaled to fit the screen, maintaining the aspect ratio determined by the trial-by-trial randomization procedure. For all stimuli (faces and logos), participants were instructed: “Please adjust the window until the image looks right”.

Results and Discussion

Mean absolute errors are shown in table 4. A mixed model ANOVA (between subjects factor: Stimulus type, faces/logos; within subjects factor: Familiarity, familiar/unfamiliar) showed significant main effects of stimulus type, $F(1, 58) = 185.4, p < .001, \eta_p^2 = .76$, and familiarity, $F(1, 58) = 100.9, p < .001, \eta_p^2 = .64$, and a significant interaction, $F(1, 58) = 97.7, p < .001, \eta_p^2 = .63$. Simple main effects analysis showed no effect of familiarity for faces ($F(1, 58) < 1$). However, there was a significant advantage for familiar over unfamiliar logos ($F(1, 58) = 198.6, p < .001, \eta_p^2 = .77$)

Table 4. Experiment 3: Mean absolute error by condition (SDs in parentheses)

	Faces	Logos
Familiar	0.091 (0.039)	0.158 (0.040)
Unfamiliar	0.092 (0.038)	0.340 (0.092)

Once again we fail to find any evidence for an advantage of familiar over unfamiliar faces. Logos produced larger errors overall, roughly 16% and 34%. However, for these stimuli, there was a clear advantage for the familiar items. This demonstrates that the resizing task will show effects of familiarity where they exist, providing further support for this rather counter-intuitive absence of an advantage for familiar over unfamiliar faces.

General discussion

The task used in this series of experiments was intended to access people's representations of the faces they know. It goes beyond a simple recognition task, asking people to generate a picture which matches their knowledge of that person's face. Despite this, people were consistently poor, showing no advantage for familiar over unfamiliar faces. Indeed, in one experiment, participants were *worse* for familiar faces. Moreover, we found that the task was performed significantly worse than resizing geometric colour patches (Experiment 2) and an advantage for resizing familiar over unfamiliar brand logos (Experiment 3), suggesting that our methods can exhibit a familiarity advantage for stimuli other than faces.

These experiments seem to pose a challenge to theories of configural processing recruiting metric distances between features, as they are applied to recognition of familiar faces (Diamond & Carey, 1986; Maurer et al, 2002). However, given the very large range of theories which come under the title 'configural processing', it is certainly not possible to rule them all out. Perhaps the underlying spatial layout we use to recognise familiar faces is unaffected by changes in aspect ratio – at least within a range of 8% to 13% deviation as demonstrated here. It may be possible to find a set of measurements which can be extracted from any recognizable view of a known face, and which meet this constraint, despite the fact that this has not been offered yet, in over 30 years of relevant research. However, this will be difficult, because simple angles and ratios exceeding one dimension are excluded by our data. At the least, these results provide a constraint on the eventual operationalization of configural processing.

A more radical explanation for these results is that we do not use the 'subtle differences in spatial relations between face features' to recognise one another at all. We have argued that faces become familiar through an abstraction of instances across many variants of the same face (Burton, Jenkins, Hancock, & White, 2005; Jenkins et al., 2011) and have demonstrated that such an abstraction can support improved computational face recognition (Jenkins & Burton, 2008). Such an approach is certainly holistic, but it acknowledges that metric distances in particular instances of face will be inherently variable. If this is true, then one would expect one's representation of familiar faces to be *tolerant* to variation, not hyper-specific - which does seem to be the pattern of results presented in this paper.

Finally, we should be clear that we are not advocating a feature-based alternative to configural processing. Although configural accounts are often contrasted with featural accounts of recognition (e.g., see Tanaka & Sengco, 1997; Rakover, 2002), the data presented here provide no evidence that discriminates between the two. Indeed, since many part-based accounts rely on accurate representations of individual features, these are equally compromised by the evidence we have presented. One might plausibly expect that accurate representation of features requires accurate representation of their aspect ratio (their shape). If participants were able to call on this knowledge, then we might expect them to use it as a route to accurate performance in our experimental task. Furthermore, we are not suggesting that the notion of holistic processing in face recognition be abandoned. Indeed, there is overwhelming evidence from a variety of sources that some form of holistic processing takes place in face processing: for example, the composite face effect (Hole, 1994; Young, Hellawell, & Hay, 1987; Rossion, 2013), effects of feature displacement (e.g., Searcy & Bartlett, 1996; Tanaka & Sengco, 1997), and the fact that isolated feature recognition is poor (e.g., Tanaka & Farah, 1993; Tanaka & Sengco, 1997; but see Wenger & Ingvalson, 2002, 2003). How, then is it possible to retain the notion of holistic processing, without employing simple definitions of configural processing relying on metric distance between features?

In fact, many computational approaches to face recognition are componential, without the need to measure distances in the picture plane. For example, Principal Components Analysis has been extensively used in artificial systems (e.g. Turk & Pentland, 1991; Kirby & Sirovich, 1990), as well as in explanations of human face perception (e.g. O'Toole, Abdi, Deffenbecher & Valentin, 1993; Hancock, Bruce & Burton, 1998). This and related techniques can provide a low-dimensional parameterization of faces in which all components cover the entire face. Such techniques give strong weight to reflectance properties of the face (sometimes called 'surface' or 'texture'), which are entirely absent from traditional notions of configural processing. It will perhaps be necessary to incorporate this information into theories of human perception.

To conclude, we have provided evidence that is challenging for a simple account of

configural processing, as a mechanism for recognizing familiar faces. At the least, these results provide constraints for the development of such models. However, we have also proposed that a proper understanding of face discrimination must incorporate the fact that faces display considerable within-person variance, and we therefore anticipate that any future theory will need to account for tolerance to this variation as faces become familiar. Although we are not in a position to offer an alternative to a configural view of face recognition, this is not a counsel of despair. It is possible to accommodate holistic face processing within a computational account, and it may be that insights from automatic face recognition will benefit research in human face perception.

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Appendix

Experiments 1-3: familiar and unfamiliar faces

UK celebrities (familiar to the participants): Ryan Giggs, Gareth Gates, Dermot O’Leary, Fearne Cotton, Graham Norton, Vernon Kay, Carol Vorderman, Alan Davies, Rob Brydon, James Nesbitt, Jessie Wallace, Karren Brady, Les Dennis, Steve McFadden, Shane Richie.

Australian celebrities (unfamiliar to the participants): Sandra Sully, Ricki-Lee Coulter, Nikki Webster, Peter Garrett, Miranda Kerr, Hamish Blake, Jessica Rowe, Missy Higgins, Bert Newton, Delta Goodrem, Matt Moran, Kate Ritchie, Dave Hughes, Rebecca Cartwright, Anthon Callea.

Experiment 3: familiar and unfamiliar logos

Familiar: Apple, BP, Dreamworks, Facebook, Lacoste, McDonalds, Microsoft, Nike, Pepsi, PlayStation, Reebok, Shell, Volkswagen, Wikipedia, WWF.

Unfamiliar: CBC, A&W, Air Transat, Boston Pizza, Canadian Tire, Cineplex, Giant Tiger, Loblaw’s, Lululemon, Manulife, Potash Corp, RBC, Rogers, Scotia Bank, Telus.